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IN ACCORDANCE WITH A DIRECTIVE FROM THE COLORADO DEPARTMENT OF HEALTH, THE REINJECTION WATER AT THE NORTH BOUNDARY OF RMA WILL BE SUBJECT TO DRINKING WATER STANDARDS AS ESTABLISHED BY THE U.S. EPA AND THE CDH. IN ADDITION TO ORGANIC LIMITATIONS FOR WHICH PURPOSE THE GRANULAR ACTIVATED CARBON SYSTEM WAS INSTALLED, THERE IS ALSO A SPECIFIC LIMIT OF 2.4 MG/L OF FLUORIDE. THE PURPOSE OF THIS STUDY WAS TO DETERMINE THE TECHNO-ECONOMIC FEASIBILITY OF THE ACTIVATED ALUMINA PROCESS TO REMOVE EXCESS FLUORIDE FROM THE CARBON TREATED WATER. THE STUDY INCLUDED DATA ON PH AND FLUORIDE LEVELS OF THE RAW AND TREATED WATER THROUGH TWO EXHAUSTION CYCLES OF THE ALUMINA AND TWO CHEMICAL REGENERATION CYCLES. PRELIMINARY CHEMICAL USAGE, OPERATING AND CAPITAL COSTS ARE PRESENTED ALONG WITH THE TEST ANALYTICAL RESULTS.



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# FEASIBILITY STUDY
# FOR THE
# REMOVAL OF EXCESS FLUORIDE
# FROM
# ACTIVATED CARBON EFFLUENT

FOR

THE DEPARTMENT OF THE ARMY

ROCKY MOUNTAIN ARSENAL

(REF. #DAAA05-78-M-0914)

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Rubel and Hager, Inc.
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September 30, 1978

Project Authorization:

Project Manager for Chemical Demilitarization
and Installation Restoration
Aberdeen Proving Ground, MD
ITARMS Project No. 1.05.15

# I N D E X

# FEASIBILITY STUDY FOR THE REMOVAL OF EXCESS FLUORIDE FROM ACTIVATED CARBON EFFLUENT

## I. Introduction

In accordance with a directive from the Colorado Department of Health, the reinjection water at the north boundary of the Rocky Mountain Arsenal will be subject to drinking water standards as established by the U. S. Environmental Protection Agency and the Colorado Department of Health (see Appendix H). In addition to organic limitations for which purpose the granular activated carbon system was installed, there is also a specific limit of 2.4 mg/l of fluoride. This directive is consistant with similar actions presently underway in many states including Arizona, California, Texas relating to fluoride in potable ground water supplies. The purpose of this study was to determine the techno-economic feasibility of the activated alumina process to remove excess fluoride from the carbon treated water. The study included data on pH and fluoride levels of the raw and treated water through two (2) exhaustion cycles of the alumina and two chemical regeneration cycles.

Preliminary chemical usage, operating and capital costs are presented along with the test analytical results.

## II. Test Description

### A. General Procedures.

The test apparatus schematically shown in Appendix F was installed on September 11, 1978 adjacent to the activated carbon system in the north boundary treatment building and was operated through September 23, 1978.

The test apparatus included a ten-inch diameter by five foot high PVC column containing one cubic foot of activated alumina (Alcoa F-1, 28 x 48 mesh).

During each run the pH of the carbon treated water was adjusted downward by the addition of $H_2SO_4$ and the water then passed downflow through the alumina at a flow rate between 1.5 and 1.6 gpm. Samples of the pH adjusted raw water and treated water were periodically examined for fluoride and pH levels.

Comparative analyses between on-site fluoride tests and RMA analytical laboratories indicated a very close correlation throughout the study (see Appendix G).

Samples of the regeneration effluent were collected in 50 and 100 gallon composites and the concentration of the fluoride determined.

### B. Discussion.

Removal of fluoride from the carbon treated water by the activated alumina process proceeded as expected during the first run achieving levels of 0.25 mg/l for part of the run. In all 13,320 gallons were treated with an

with 42 million gallons/year ∴ 3156 cycles/$FT^3$

average fluoride level of 1.04 mg/l (Appendix A). This represents an alumina capacity of 2,781 grains per cubic foot.

Regeneration of the alumina following the first run proceeded normally but the pH of the effluent solution did not achieve expected levels of 12+. Analysis of the composite sample regeneration fluids indicated incomplete removal of fluoride from the bed. Therefore, a second regeneration was performed. Data (Appendix C) indicates that 2,400 grains of fluoride were recovered from both regenerations. This represents 85% of the total fluoride removed during the first run. In the second run as in the first, fluoride levels reached the 0.25 mg/l level for a portion of the run and 11,325 gallons were treated with an average fluoride concentration of 1.00 mg/l. This represents a capacity of 2,440 grains of fluoride per cubic foot of alumina.

The second regeneration of the alumina proceeded normally. Data on the composite sample of regenerate solution indicated a total recovery of 1,880 grains of fluoride. Again as in the first regeneration, this represents incomplete (79%) recovery of the fluoride from the bed.

An additional regeneration test was performed on the alumina bed which had undergone the aforementioned two exhaustion and two regeneration cycles. One tenth (1/10) of a cubic foot of alumina was placed in a two-inch column

and treated with 1.5% NaOH in the same manner as the on-site study. Approximately, fifty-three grains of fluoride was removed which would equate to 530 grains in the one cubic foot test bed of alumina. Since 1,880 grains had previously been extracted, the total recovery extrapolates to 2,410. This compares reasonably well to the total fluoride removed during the second exhaustion cycle of 2,440 grains per cubic foot.

While outside the scope of this study, tests for other chemical constituents such as boron and total organic carbon (TOC) indicate some variability in the quality of the water being treated. The drop in fluoride removal capacity of the alumina (2,781 to 2,440 grains per cubic foot) between Run I and II suggest the presence of chemical constituents which compete with fluoride for alumina sites.

## III. Preliminary Process Design

The following parameters were used to outline a proposed full-scale treatment facility:

| | | |
|---|---|---|
| 1. | Location: | Northeast corner of the carbon treatment building at north boundary. Treatment units inside - chemical storage outside. |
| 2. | Pumping: | Provided by carbon system. |
| 3. | Backwashing Water: | Taken from effluent of on-stream carbon. treatment units. |

4. Utilities: Electrical - within building.

Air - within building.

Water - carbon treated effluent.

5. Operator: Available from present staff.

6. Chemical Delivery: From bulk trucks.

7. Flow Rate: 80 - 200 gpm.

8. Wastewater Handling: Evaporation pond.

9. Instrumentation: Flow regulator and totalizer, pH controller and indicator.

The treatment units would consist of four (4) adsorbers containing 140 cubic feet of activated alumina with appropriate underdrain piping and head room to allow periodic backwashing. A day tank will feed acid in proportion to the flow and in response to pH controllers. The acidified water will be processed downflow in three of the four tanks. The fourth unit will be in reserve each cycle.

Acid and caustic storage tanks located outside and adjacent to the alumina process equipment will supply chemicals to the day tanks. Caustic regeneration of the alumina will occur for the first of the treatment vessels when the blended effluent approaches the treatment objective of 1 mg/l. Each alumina bed will be placed in service on a staggered startup basis to effect sequential exhaustion of each of the four treatment beds. This allows blending of effluents for greater economy.

Regenerate fluids including rinse waters will be diverted to a lined evaporation pond adjacent to the treatment building.

The existing carbon plant operations personnel will be required to monitor performance, fill the day tanks, take samples, and to perform regeneration procedures.

## IV. Capital and Operating Cost Projections

### A. Capital Costs.

| | | |
|---|---|---|
| Process Equipment | | $60,000.00 |
| Treatment vessels | $15,000.00 | |
| Process piping and instrumentation | 15,000.00 | |
| Activated alumina | 8,000.00 | |
| Chemical storage vessels | 15,000.00 | |
| Chemical pumps, piping and accessories | 7,000.00 | |
| Process Equipment Installation | | 32,000.00 |
| Lined Evaporation Pond | | 50,000.00 |
| | Subtotal | $142,000.00 |
| Contingency and Contractors Profit | | 20,000.00 |
| Engineering | | 25,000.00 |
| Services | 20,000.00 | |
| Expenses | 5,000.00 | |
| | TOTAL | $187,000.00 |

*Based upon September 1978 prices

B. Operating Costs.

The chemical costs developed during the study are summarized in Appendix E. These data are based upon an average capacity of 2,600 grains per cubic foot of alumina for removal of 5.0 to 4.0 mg/l of fluoride to a 1 mg/l average level. The projected acid consumption can be extrapolated from the test results (Appendix E) with reasonable certainty. On the other hand, caustic consumption during the test was not firmly established. Higher than normal amounts of regenerate was used in the first cycle regeneration. Additionally, the second cycle exhausted alumina did not release all of the fluoride removed in the second cycle. Until additional testing develops more precise data, it is necessary to project higher than normal caustic costs. Therefore, the projected costs which follow assume the caustic requirements to be that used during the test. Additionally, the working capacity is projected at 2,000 grains per cubic foot which is only 75% obtained during the study.

Using these parameters the operating costs can be projected as follows:

| | $ per 1,000 Gallons |
|---|---|
| 1. Chemicals | |
| 66 Be $H_2SO_4$ @ $60/Ton | $0.056 |
| 50% NaOH $205/Ton | 0.136 |
| 2. Alumina Replacement | |
| 3% per year @ 40¢ pound | 0.010 |

@ 20% loss of efficiency each cycle
∤ 3156 cycles/$FT^3$ ÷ $\frac{1}{140}$ = 22 cycles ∴ 5 replacements

| | | |
|---|---|---|
| 3. | Operator (existing) | -- |
| 4. | Electricity (existing) | -- |
| 5. | Miscellaneous Supplies/Service | 0.02 |
| | | $.212 |

The high caustic regeneration projected costs results from a higher price for caustic in truck deliveries vs. rail (205/Ton vs. $179/Ton) and inefficient caustic regeneration during the test. Further study should develop more effective regeneration procedure and thus reduce operating costs.

## V. Conclusions and Recommendations

Using the activated alumina process, this study demonstrated that excess fluoride can be removed from the carbon treated water at the reinjection site of the northern boundary of the Rocky Mountain Arsenal. This study consisting of two complete treatment cycles including chemical regeneration demonstrated the removal of fluoride from levels of 4-5 mg/l to an average 1 mg/l or less. Additionally, a capacity of more than 2,000 grains of fluoride per cubic foot of alumina was achieved. This fluoride removal performance is better than the specific limitations cited by the EPA and the Colorado Department of Health of 2.4 mg/l.

A full-scale treatment plant rated for 80-200 gallons per minute is projected to cost $187,000.00 for engineering design, installation and start-up. Operating costs are pro-

jected to be 21 cents per 1,000 gallons utilizing the existing personnel and available pumping. Improved operating costs are likely to be developed if additional cyclic tests are performed to optimize caustic regeneration.

A lined evaporation pond was included in the capital cost projections since this method of wastewater handling has been used successfully in Arizona projects. There are other methods of disposal which can be considered if evaporation ponds are inappropriate at this site. what

It is recommended that the Rocky Mountain Arsenal proceed with the design and installation of a full-scale fluoride system in order to comply with Colorado Department of Health directives.

Concurrent to the engineering design effort, a laboratory study is recommended to analyze the retained samples from this study of raw and treated water along with regenerate fluid to determine if any other chemical constituents (in addition to fluoride) are being retained on the alumina and/or released during regeneration.

Based on these analyses additional alumina exhaustion and regeneration cycles should then be performed to optimize the caustic regeneration procedure for maximum long term economy.

## LIST OF APPENDICES

# APPENDIX A

## TEST RUN NO. 1 DATA TABULATION

| Time (hrs:min) | Δ Gals Treated | Total Gals Treated | Adj RW pH | TW pH | RW F mg/l | TW F mg/l | Δ Ave F mg/l | Δ Grains Removed | Total Grains Removed | TW Ave F mg/l |
|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0 | 0 | 5.0 | 10+ | 4.1 | | | | | |
| 0:30 | 50 | 50 | 5.0 | 8.2 | | 0.95 | 0.95 | 9 | 9 | 0.95 |
| 1:00 | 50 | 100 | 5.0 | 7.8 | 4.1 | 0.70 | 0.87 | 10 | 19 | 0.91 |
| 1:30 | 40 | 140 | 5.0 | 7.6 | | 0.68 | 0.69 | 8 | 27 | 0.84 |
| 2:15 | 60 | 200 | 5.5 | 7.5 | | 0.66 | 0.67 | 12 | 39 | 0.79 |
| 2:45 | 50 | 250 | 5.5 | 7.5 | | 0.61 | 0.63 | 10 | 49 | 0.76 |
| 7:15 | 400 | 650 | 5.5 | 6.5 | | 0.25 | 0.43 | 86 | 135 | 0.55 |
| 14:15 | 610 | 1260 | 5.5 | 5.9 | | 0.25 | 0.25 | 138 | 273 | 0.41 |
| 18:15 | 360 | 1620 | 5.5 | 5.8 | | 0.25 | 0.25 | 82 | 355 | 0.37 |
| 19:15 | 90 | 1710 | 5.5 | 5.8 | | 0.25 | 0.25 | 20 | 375 | 0.37 |
| 22:15 | 270 | 1980 | 5.5 | 5.7 | | 0.25 | 0.25 | 61 | 436 | 0.35 |
| 24:45 | 180 | 2160 | 5.5 | 5.7 | | 0.30 | 0.27 | 41 | 477 | 0.34 |
| 28:45 | 390 | 2550 | 5.5 | 5.6 | 4.8 | 0.30 | 0.30 | 103 | 580 | 0.34 |
| 32:45 | 390 | 2940 | 5.5 | 5.6 | | 0.25 | 0.28 | 94 | 674 | 0.33 |
| 38:45 | 610 | 3550 | 5.5 | 5.5 | | 0.25 | 0.25 | 163 | 837 | 0.32 |
| 42:15 | 350 | 3900 | 5.5 | 5.5 | 4.6 | 0.25 | 0.25 | 89 | 926 | 0.31 |
| 44:15 | 190 | 4090 | 5.5 | 5.5 | | 0.30 | 0.28 | 48 | 974 | 0.31 |
| 47:45 | 360 | 4450 | 5.5 | 5.5 | | 0.30 | 0.30 | 91 | 1065 | 0.31 |
| 51:15 | 350 | 4800 | 5.5 | 5.5 | | 0.30 | 0.30 | 89 | 1154 | 0.31 |
| 56:15 | 510 | 5310 | 5.5 | 5.5 | | 0.35 | 0.32 | 128 | 1282 | 0.31 |
| 62:45 | 650 | 5960 | 5.5 | 5.5 | 5.0 | 0.50 | 0.43 | 175 | 1457 | 0.32 |
| 67:15 | 440 | 6400 | 5.5 | 5.5 | 4.9 | 0.70 | 0.60 | 111 | 1568 | 0.34 |
| 69:15 | 200 | 6600 | 5.5 | 5.5 | | 0.72 | 0.71 | 49 | 1617 | 0.35 |
| 72:15 | 300 | 6900 | 5.5 | 5.5 | 4.8 | 0.82 | 0.77 | 71 | 1688 | 0.37 |
| 73:15 | 100 | 7000 | 5.5 | 5.5 | | 0.85 | 0.83 | 23 | 1711 | 0.38 |
| 76:15 | 300 | 7300 | 5.5 | 5.5 | | 0.88 | 0.86 | 69 | 1780 | 0.40 |
| 78:15 | 200 | 7500 | 5.5 | 5.5 | 5.0 | 0.93 | 0.91 | 48 | 1828 | 0.41 |
| 81:15 | 290 | 7790 | 5.5 | 5.5 | | 0.98 | 0.95 | 69 | 1897 | 0.43 |

APPENDIX A

TEST RUN NO. 1 DATA TABULATION

| Time (hrs:min) | $\Delta$ Gals Treated | Total Gals Treated | Adj RW pH | TW pH | RW F mg/l | TW F mg/l | $\Delta$ Ave F mg/l | $\Delta$ Grains Removed | Total Grains Removed | TW Ave F mg/l |
|---|---|---|---|---|---|---|---|---|---|---|
| 87:00 | 600 | 8390 | 5.5 | 5.5 | 4.6 | 1.15 | 1.05 | 125 | 2022 | 0.47 |
| 91:45 | 458 | 8848 | 5.5 | 5.5 | 4.6 | 1.35 | 1.25 | 90 | 2112 | 0.51 |
| 95:45 | 422 | 9270 | 5.5 | 5.5 | 4.75 | 1.55 | 1.45 | 82 | 2194 | 0.56 |
| 97:15 | 140 | 9410 | 5.5 | 5.5 | | 1.80 | 1.67 | 25 | 2219 | 0.57 |
| 98:45 | 560 | 9970 | 5.5 | 5.5 | | 1.90 | 1.85 | 96 | 2315 | 0.64 |
| 102:45 | 800 | 10770 | 5.5 | 5.5 | 4.90 | 1.95 | 1.92 | 140 | 2455 | 0.74 |
| 114:45 | 200 | 10970 | 5.5 | 5.5 | | 2.10 | 1.04 | 45 | 2500 | 0.75 |
| 119:45 | 510 | 11480 | 5.5 | 5.5 | | 2.20 | 2.15 | 83 | 2583 | 0.81 |
| 123:45 | 390 | 11870 | 5.5 | 5.5 | 4.70 | 2.50 | 2.35 | 54 | 2637 | 0.86 |
| 129:15 | 900 | 12770 | 5.5 | 5.5 | | 2.80 | 2.65 | 93 | 2730 | 0.98 |
| 135:15 | 460 | 13230 | 5.5 | 5.5 | | 2.80 | 2.80 | 51 | 2781 | 1.04 |

## APPENDIX B

### TEST RUN NO. 2 DATA TABULATION

| Time (hrs:min) | Δ Gals Treated | Total Gals Treated | Adj RW pH | TW pH | RW F mg/l | TW F mg/l | Δ Ave F mg/l | Δ Grains Removed | Total Grains Removed | TW Ave F mg/l |
|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | | | | 11.8 | 4.7 | 5.0 | | | | |
| 0:15 | 20 | 20 | 3.0 | 11.4 | | 2.2 | 3.6 | 1 | 1 | 3.60 |
| 0:30 | 45 | 65 | | 11.2 | | 1.5 | 1.8 | 8 | 9 | 2.3 |
| 1:00 | 47 | 112 | 3.0 | 10.8 | | 0.58 | 1.0 | 10 | 19 | 1.6 |
| 5:15 | 413 | 525 | 4.5 | 6.4 | | 0.25 | 0.42 | 104 | 123 | 0.67 |
| 6:45 | 133 | 658 | 5.5 | 5.6 | | 0.25 | 0.25 | 35 | 158 | 0.59 |
| 11:15 | 559 | 1217 | 5.5 | 5.6 | | 0.25 | 0.25 | 146 | 304 | 0.43 |
| 12:15 | 101 | 1318 | 5.5 | 5.6 | | 0.25 | 0.25 | 26 | 330 | 0.42 |
| 12:45 | 50 | 1368 | 5.5 | 5.6 | 4.7 | 0.25 | 0.25 | 13 | 343 | 0.41 |
| 16:45 | 405 | 1773 | 5.5 | 5.5 | | 0.25 | 0.25 | 106 | 449 | 0.37 |
| 21:30 | 487 | 2260 | 5.5 | 5.5 | | 0.25 | 0.25 | 127 | 576 | 0.35 |
| 29:00 | 770 | 3030 | 5.5 | 5.5 | | 0.25 | 0.25 | 202 | 778 | 0.32 |
| 33:15 | 525 | 3555 | 5.5 | 5.5 | 4.7 | 0.25 | 0.25 | 137 | 915 | 0.31 |
| 37:15 | 405 | 3960 | 5.5 | 5.5 | | 0.25 | 0.25 | 106 | 1021 | 0.30 |
| 41:15 | 395 | 4355 | 5.5 | 5.5 | | 0.30 | 0.27 | 103 | 1124 | 0.30 |
| 45:15 | 312 | 4667 | 5.5 | 5.5 | | 0.35 | 0.33 | 80 | 1204 | 0.30 |
| 54:15 | 923 | 5590 | 5.5 | 5.5 | 4.7 | 0.60 | 0.47 | 230 | 1434 | 0.33 |
| 59:15 | 400 | 5990 | 5.5 | 5.5 | | 0.75 | 0.67 | 93 | 1527 | 0.35 |
| 64:15 | 500 | 6490 | 5.5 | 5.5 | | 0.90 | 0.82 | 114 | 1641 | 0.39 |
| 68:15 | 500 | 6990 | 5.5 | 5.5 | | 1.00 | 0.95 | 110 | 1751 | 0.43 |
| 72:15 | 395 | 7385 | 5.5 | 5.5 | | 1.40 | 1.20 | 81 | 1832 | 0.47 |
| 77:45 | 405 | 7790 | 5.5 | 5.5 | | 1.60 | 1.50 | 100 | 1932 | 0.52 |
| 79:45 | 260 | 8050 | 5.5 | 5.5 | | 1.70 | 1.65 | 47 | 1978 | 0.56 |
| 83:15 | 350 | 8400 | 5.5 | 5.5 | | 1.80 | 1.75 | 61 | 2040 | 0.61 |
| 87:15 | 400 | 8800 | 5.5 | 5.5 | | 1.90 | 1.85 | 67 | 2107 | 0.67 |

## APPENDIX B

### TEST RUN NO. 2 DATA TABULATION

| Time (hrs:min) | Δ Gals Treated | Total Gals Treated | Adj RW pH | TW pH | RW F mg/1 | TW F mg/1 | Δ Ave F mg/1 | Δ Grains Removed | Total Grains Removed | TW Ave F mg/1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 90:15 | 290 | 9090 | 5.5 | 5.5 | | 2.0 | 1.95 | 47 | 2154 | 0.70 |
| 94:15 | 300 | 9390 | 5.5 | 5.5 | | 2.2 | 2.10 | 46 | 2200 | 0.75 |
| 102:45 | 710 | 10100 | 5.5 | 5.5 | | 2.3 | 2.25 | 102 | 2224 | 0.86 |
| 104:15 | 170 | 10270 | 5.5 | 5.5 | | 2.3 | 2.3 | 24 | 2248 | 0.88 |
| 107:15 | 260 | 10530 | 5.5 | 5.5 | | 2.3 | 2.3 | 37 | 2285 | 0.91 |
| 111:15 | 375 | 10905 | 5.5 | 5.5 | | 2.3 | 2.3 | 53 | 2338 | 0.96 |
| 115:00 | 375 | 11325 | 5.5 | 5.5 | | 2.4 | 2.35 | 51 | 2440 | 1.00 |

## APPENDIX C

### REGENERATION OF ACTIVATED ALUMINA

### FOLLOWING TEST RUN NO. 1

| Time (hrs:min) | Total Gals Caustic | Total Gals Rinse | gpm/ft$^2$ | TW pH | $\Delta$ Gr F | |
|---|---|---|---|---|---|---|
| 0:00 | | | 4.8 | | | Start rinse |
| 0:20 | | 52 | | | | Stop rinse - drain tank |
| 1:00 | | | 1.1 | | | Start regeneration solution upflow |
| 1:28 | 17[a)] | | | | | Stop regeneration solution |
| 1:42 | | | 2.8 | | | Start rinse - collect in 55 gallon barrel |
| 1:45 | | | | 11.4 | | Too low! |
| 1:55 | | | | 11.2 | | |
| 2:03 | | | | 10.6 | | |
| 2:15 | | 55 | | 9.6 | 734 | First barrel full F = 240 mg/l |
| | | | | | | Start second barrel |
| 2:25 | | | | 9.2 | | |
| 2:35 | | | 4.6 | 9.0 | | Increased flow |
| 2:45 | | 55 | | 8.6 | 291 | Second barrel full F = 90 ppm - stop rinse |
| 3:05 | | | 1.1 | | | Start regeneration solution downflow |
| 3:33 | 17[b)] | | | 11.6 | | Stop regeneration solution |
| 4:31 | | | 2.8 | | | Start downflow rinse |
| 7:15 | | 200 | | 9.2 | | Stop rinse |
| | | | | | 676 | Composite 100 gallons F = 115 mg/l |
| | | | | | 64 | Composite 100 gallons F = 11 mg/l |
| 7:20 | | | 1.1 | | | Insufficient F recovery - start regeneration |
| 7:48 | 17[c)] | | | 11.5 | | |
| 7:50 | | | 0.9 | | | Start additional downflow regeneration solution |
| 8:18 | 10[d)] | | | 12+ | | Start rinse |
| 10:03 | | 98 | | | 808 | Composite 125 gallons F = 110 mg/l |

Total F Recovery = 2573 gr

a) 900 ml of 50% NaOH in 17 gallons of water
b) 1100 ml of 50% NaOH in 17 gallons of water
c) 1100 ml of 50% NaOH in 17 gallons of water
d) 1100 ml of 50% NaOH in 10 gallons of water

## APPENDIX D

### REGENERATION OF ACTIVATED ALUMINA

### FOLLOWING TEST RUN NO. 2

| Time (hrs:min) | Total Gals Caustic | Total Gals Rinse | $\frac{gpm}{ft^2}$ | TW pH | $\Delta$ Gr F | |
|---|---|---|---|---|---|---|
| 0:00 | | | | | | Drain tank |
| 0:20 | | | 1.1 | | | Start upflow regeneration solution |
| 0:50 | 20 a) | | 3.7 | | | Stop regeneration solution - start rinse and collect in 55 gallon barrel |
| 0:57 | | | | 7.5 | | |
| 1:00 | | | | 12+ | | |
| 1:13 | | | | 12 | | |
| 1:25 | | 55 | | 11.6 | 1219 | Barrel full F - 375 mg/l |
| 1:40 | | | | 11.5 | | |
| 1:53 | | | | | 244 | Second barrel full F = 112 mg/l - stop upflow rinse |
| 2:15 | | | 1.1 | | | Start downflow regeneration solution |
| 2:30 | 20 b) | | | | | Stop regeneration solution - start downflow rinse |
| 3:30 | | | | 11.4 | | Increase flow |
| 3:50 | | | | 10.8 | | |
| 4:05 | | 200 | | 10.6 | | Stop rinse |
| | | | | | 382 | Composite 100 gallons rinse F = 65 mg/l |
| | | | | | 35 | Composite 100 gallons rinse F = 6 mg/l |

Total F Recovery = 1880 gr

a) 1550 ml of 50% NaOH in 20 gallons of water
b) 1550 ml of 50% NaOH in 20 gallons of water

# APPENDIX E

## CHEMICAL CONSUMPTION DATA - FEASIBILITY STUDY

### Acid

| | | |
|---|---|---|
| Run No. 1 | 4,700 ml 66° Be $H_2SO_4$ | for 13,230 gallons of treated water |
| Run No. 2 | 4,000 ml | for 11,325 gallons of treated water |
| | 8,700 | 24,555 |

2,298 gallons per 24,555 gallons of treated water
0.092 gallons per/1,000 gallons of treated water
1.38 gallons per/1,000 gallons of treated water

@ $60/Ton = 0.041 cents per/1,000 gallons of treated water

### Caustic

| | |
|---|---|
| Regeneration No. 1 | 4,200 ml 50% NaOH |
| No. 2 | 3,100 ml 50% NaOH |
| | 7,300 per 24,555 gallons of treated water |

1929. gallons per 24,500 gallons of treated water
0.077 gallons per/1,000 gallons of treated water

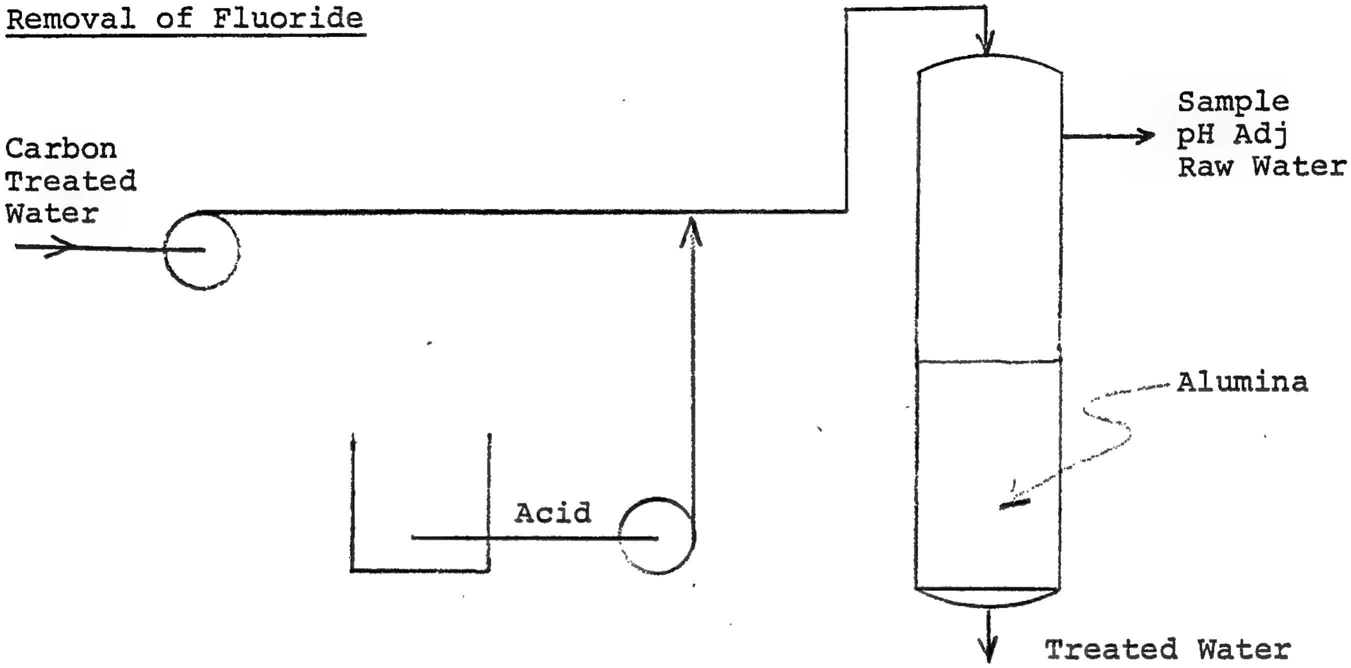
0.98 pounds per/1,000 gallons of treated water

@ $205/Ton = 0.10 cents per/1,000 ggallons of treated water

APPENDIX F

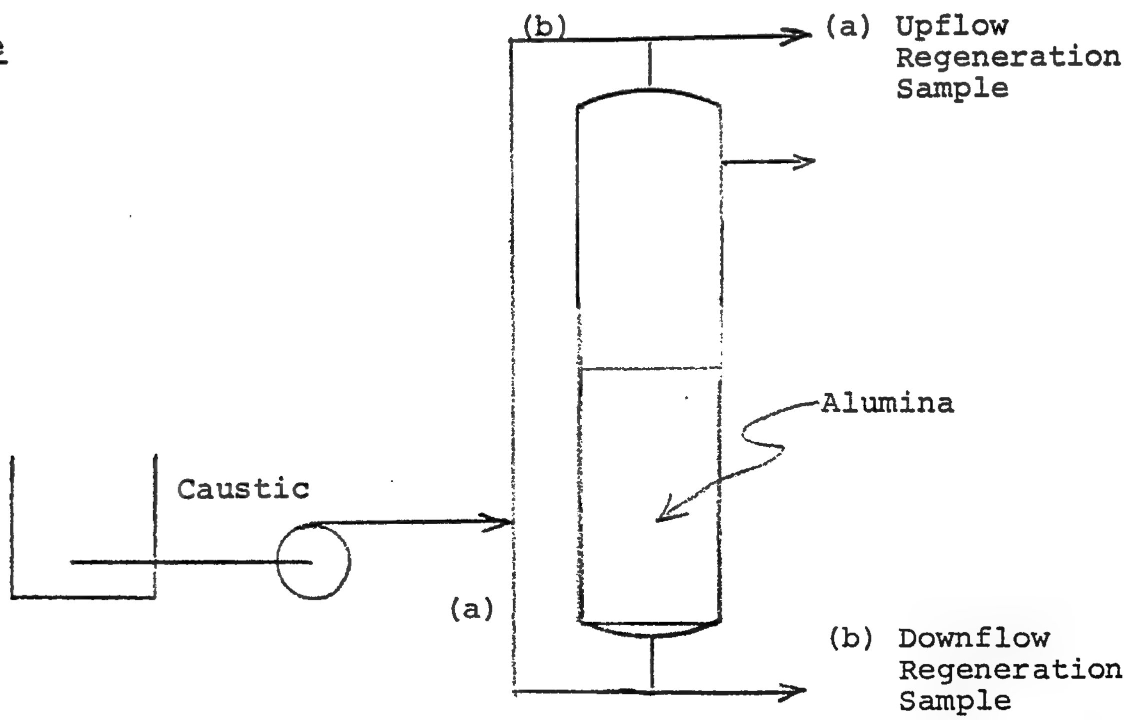
TEST APPARATUS SCHEMATIC

Removal of Fluoride




Regeneration Cycle

(a) Upflow
(b) Downflow



APPENDIX G

FLOURIDE ANALYSES COMPARISONS

| Sample No. | Gallons Treated | On Site Analysis* mg/l | RMA Specific ion mg/l | RMA Technicon mg/l |
|---|---|---|---|---|
| **Run No. 1** | | | | |
| 1 | 140 | 0.68 | 0.15 | less than 0.20 |
| 2 | 650 | 0.25 | less than 0.10 | less than 0.20 |
| 3 | 1,260 | 0.25 | less than 0.10 | less than 0.20 |
| 4 | 3,550 | 0.25 | less than 0.10 | less than 0.20 |
| 5 | 5,310 | 0.35 | 0.12 | less than 0.20 |
| 6 | 5,960 | 0.50 | 0.46 | 0.50 |
| 7 | 6,900 | 0.82 | 0.56 | 0.59 |
| 8 | 8,390 | 1.15 | 1.10 | 1.17 |
| 9 | 9,270 | 1.55 | 1.40 | 1.49 |
| 10 | 9,970 | 1.90 | 1.64 | 1.71 |
| 11 | 10,970 | 2.10 | 2.00 | 2.04 |
| 12 | 11,870 | 2.50 | 2.16 | 2.24 |
| 13 | 13,230 | 2.80 | 2.69 | 2.87 |
| **Run No. 2** | | | | |
| 1 | 320 | | 1.58 | 1.64 |
| 2 | 830 | 0.25 | 0.35 | 0.34 |
| 3 | 2,063 | 0.25 | less than 0.10 | less than 0.20 |
| 4 | 3,030 | 0.25 | less than 0.10 | less than 0.20 |
| 5 | 4,667 | 0.35 | 0.18 | 0.20 |
| 6 | 5,590 | 0.60 | 0.60 | 0.62 |
| 7 | 6,490 | 0.90 | 1.21 | 1.14 |
| 8 | 8,800 | 1.90 | 2.10 | 1.91 |
| 9 | 10,100 | 2.30 | 2.20 | 2.16 |

* Hach DR 2 Spectrophotometer

APPENDIX H

COLORADO DEPARTMENT OF HEALTH

4210 EAST 11TH AVENUE · DENVER, COLORADO 80220 · PHONE 388-6111

Anthony Robbins, M.D., M.P.A. Executive Director

May 27, 1977

Colonel Byrne
Commanding Officer
Rocky Mountain Arsenal
Denver, Colorado 80240

Colonel Byrne:

Several times in the past, Arsenal personnel have requested guidance on the quality of the reinjection water at the north boundary of the Rocky Mountain Arsenal.

After consideration of water use in the area north of the Rocky Mountain Arsenal, it was concluded that the quality of the reinjected water should be subject to drinking water standards. State drinking water limitations are contained in part 5 of "Standards for the Quality of Water Supplied to the Public", a copy of which is attached. The fluoride level contained in this part is incorrect and should be 2.4 mg/l as directed by Section 141.11(c) of the December 24, 1975 federal register entitled "Water Programs". In addition, Section 141.12 addresses levels for organic chemicals which should be met.

The Colorado Department of Health has reviewed the findings of the National Academy of Science relative to temporary guidelines for DIMP and DCPD in drinking waters. Based on toxicity, this Department is in agreement with the 0.3 ppm DIMP and 1.28 ppm DCPD limits. However, due to odors associated with DCPD, the reinjected water will be subject to the threshold odor number of 3, directed by part 4 of the State regulations.

If there are any questions, please contact this Department.

Very truly yours,

Robert D. Siek
Assistant Director, Department of Health
Environmental Health

RDS:RJS/emf

# APPENDIX I-A

## LABORATORY EVALUATION 30 GALLON BARREL

(.01 $ft^3$ alumina 28 x 48 mesh)

| | Time | Adjusted RW pH | RW F mg/l | TW F mg/l | TW pH | |
|---|---|---|---|---|---|---|
| 8/9/78 | 11:00 a.m. | 7.8 | 3.9 | | | Start downflow 40 Ml per minute |
| | 11:30 a.m. | | | 1.1 | 8.9 | |
| | 1:30 p.m. | 4.0 | | 0.6 | 8.5 | Adjust acid feed |
| | 2:30 p.m. | 5.5 | | 0.4 | 8.2 | Adjust acid feed |
| | 4:30 p.m. | | | 0.35 | 8.0 | |
| | 7:00 p.m. | | | 0.35 | 7.7 | |
| | 9:00 p.m. | | | 0.30 | 7.6 | Flow off |
| 8/10/78 | 9:00 a.m. | | 3.9 | | | Flow on 40 Ml per minute |
| | 9:15 a.m. | 4.0 | | 0.45 | 7.8 | Adjust acid feed |
| | 11:00 a.m. | | | 0.4 | 7.2 | |
| | 1:00 p.m. | | | 0.3 | 6.8 | |
| | 3:00 p.m. | | | 0.25 | 6.8 | Sample depleted |

CONCLUSION: The process functions normally on this water and on-site cyclic test are recommended to verify alumina capacity for fluoride removal.

## APPENDIX I-B

ANALYSIS OF 30 GALLON BARREL

ROCKY MOUNTAIN ARSENAL CARBON TREATMENT EFFLUENT

| | |
|---|---|
| Dissolved Solids @ 180°C mg/l | 1500 |
| Nitrate Nitrogen as N | less than 0.05 |
| Total Phosphate as P | 2.8 |
| Boron | 0.5 |
| Fluoride | 3.5 |
| Hardness as $CaCO_3$ | 480 |
| Arsenic | less than 0.01 |
| Barium | less than 0.1 |
| Cobalt | 0.05 |
| Manganese | 0.80 |
| Selenium | 0.012 |
| Zinc | 0.30 |
| Total Organic Carbon | 15 |